

DELAWARE BREAKWATER.

LETTER

FROM

THE SECRETARY OF WAR,

TRANSMITTING

The report of Major Bache, of the corps of topographical engineers, relative to the Delaware breakwater.

JANUARY 27, 1844.

Read, and laid upon the table.

WAR DEPARTMENT, January 23, 1844.

SIR: In answer to a resolution of the House of Representatives of the 18th instant, requiring "the Secretary of War to communicate to the House the report of Major Bache, of the corps of topographical engineers, on the Delaware breakwater," I respectfully transmit herewith a copy prepared at the Topographical Bureau of this department.

Very respectfully, your obedient servant,

J. M. PORTER.

Hon. JOHN W. JONES,

Speaker of the House of Representatives.

OFFICE OF THE DELAWARE BREAKWATER,
Philadelphia, October 15, 1843.

SIR: I have the honor to lay before the bureau the following report on the Delaware breakwater for the last year:

Since the session of 1837-'38, no appropriation has been made to continue the construction of the Delaware breakwater, and the last stone provided by that appropriation was deposited in 1839. The balance on hand at the close of that year was applied to the surveys of 1840, to the support of the light-house, and to the protection of the public property at the harbor. Prior to the 1st of February, 1841, this balance was entirely exhausted; and from that time to the 1st of March, 1842, the light was kept up by the chamber of commerce of this city. Its maintenance was then again provided for out of the fund "for arrearages due for roads, harbors, rivers, and for the protection of public property." On the 1st of September following, this appropriation was relieved from this charge by a special provision of \$1,500, made under the act of August 26, 1842, "for the support of the light-house on the Delaware breakwater." The balance of this appropriation on hand, and in the treasury, on the 1st of October, was \$334 94; to which add \$121, being the proceeds of the sales on account of the general fund for the work, making \$455 94 the aggregate available means on the 1st of October for the support of the

light. The liabilities up to the 31st of December next, including the cost of fuel and oil for the winter, will amount to about \$410; leaving on the 1st of January, 1844, a sum insufficient for the pay of the keeper and his assistant for a single month: consequently, unless early in the approaching session Congress shall provide for the occasion, or unless the chamber of commerce of this city shall again consent to take upon itself to maintain the light, it must expire—and that, too, at the season when its existence would be most useful. How detrimental such a result would be to all who have an interest in this important harbor, it is needless to describe. The simple fact that the light must soon expire, owing to the want of support, seems to be sufficient to attract early and earnest attention to the subject.

It was contemplated to illustrate, on the present occasion, the growing importance of the Delaware breakwater as a harbor, by various statistical and commercial details, and especially in connexion with the coastwise coal-trade. This intention, however, has been reluctantly relinquished, in consequence of an inability to collect such statements as might be fully confided in. The vast advantages of this work to commerce cannot, however, be more clearly manifested than by the practical results, as exhibited in the following statement. Such a statement has been heretofore presented in former reports; but the one now submitted, and made up to the 30th of September last, is not only important on its own account, but as confirmatory of former representations, showing, by the increase of the number of vessels that seek the harbor, how steadily it rises in the estimation of merchants and traders.

The following table shows the number of days' shelter afforded to vessels by the Delaware breakwater, from the 1st of September, 1833, to the 30th of September, 1843, inclusive—omitting the periods embraced between the 1st of July and the 17th of October, 1834; and the 4th of June, 1840, and the 30th April 1841, (when no record was kept;) and also omitting vessels carrying stone, or otherwise connected with the work.

Years.	Ships.	Brigs.	Schooners.	Sloops.	Pilot-boats.	Total.	Remarks.
1833	22	178	372	167	127	866	From Sept. 1st, inclusive.
1834	48	315	667	303	411	1,744	July 1st to October 17th, inclusive, not recorded.
1835	133	569	1,719	461	644	3,526	
1836	301	1,027	2,719	620	767	5,434	
1837	227	478	2,777	629	732	4,843	
1838	165	732	3,191	765	685	5,538	
1839	165	504	3,561	734	697	5,661	
1840	172	279	1,909	308	371	3,039	To June 3d, inclusive.
1841	111	902	3,916	590	483	6,002	From May 1st, inclusive.
1842	107	1,060	5,335	802	794	8,098	
1843	84	644	3,865	962	572	6,127	To Sept. 30th, inclusive.
	1,535	6,688	30,031	6,341	6,283	50,878	

Making a just allowance for the periods when no records were kept, it may be safely said, that, from its commencement to the present time, the harbor has given sixty thousand days' shelter. According to the record for the last four years, twenty-two vessels, on an average, had been lying in the harbor for each day. Sixty to seventy vessels are seen frequently lying in the harbor at the same time, and on one occasion the number of vessels reached as high as one hundred and eight.

From the 16th of January, 1838, to the 16th of October, 1839, all vessels bound coastwise were distinguished from those sailing to or from the Delaware. This classification showed the relative advantages of the harbor to the local trade, and to that of the country at large. Within the twenty-one months just mentioned, shelter for three thousand eight hundred and seventy-seven days was afforded to vessels bound along the coast, being about two-fifths of the whole number. Excluding the pilot-boats, the proportion extends to four-ninths. In other words, the benefits of the harbor were, to general commerce and the local trade, in the relation of four to five.

An estimate for the completion of the works, with their present lengths, including contingencies, and for current expenses for the fiscal year next ensuing, is hereto annexed. The objects of expenditure are explained under their several appropriate heads:

15,356 tons of stone, of pieces of two tons and upwards, to finish the breakwater proper, on its present base, to the height of fifteen feet above low water, at \$3 per ton	\$46,068 00
5,495 tons of stone, of pieces of two tons and upwards, to finish the ice breaker, on its present base, to the height of ten feet above low water, at \$3 per ton	16,485 00
15,827 tons of stone, of pieces less than one-fourth of a ton, to fill the holes at the extremities of the breakwater proper, to the level of forty feet below lowest spring tides, at \$1 75 per ton	27,697 25
Renewal and repair of machinery, boats, buoys, buoy-chains, rope, blocks, tools, handspikes, water-barrels, spikes, nails, paints, &c., necessary on resuming operations	3,125 00
Quarters for men, including cambooses, bunks, &c.	2,000 00
Extraordinary emergencies, such as the destruction of the light-house on the breakwater proper, &c.	2,000 00
Current expenses of the light-house on breakwater proper	1,500 00
Current expenses from January 1 to July 1, 1844, (probable arrearage)	750 00
Screw-piles, and fixing the same from the west end of the ice breaker towards the shore, to give protection against ice	15,000 00
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	114,625 25
Contingencies $17\frac{1}{2}$ per cent.	20,059 42
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Total amount	\$134,684 67

The commissioners who were appointed under the act of Congress of the 24th of May, 1828, to ascertain the most eligible site, and to prepare

plans and estimates for a harbor near the mouth of Delaware bay, in their report of the 2d February, 1829, selected Cape Henlopen. They said: "The objects to be gained by an artificial harbor in this roadstead are, to shelter vessels from the action of the waves caused by the winds blowing from the east to northwest, round by the north; and also to protect them against injuries arising from floating ice descending from the northwest." Having these objects in view, the commissioners propose two works: the breakwater proper, to secure the first object; and the ice-breaker, an auxiliary to the breakwater, but chiefly to accomplish the second purpose. The first-mentioned work was designed with a length of 1,200 yards, and on a course W.N.W. drawn from the pitch of the cape. The ice breaker was designed with a length of 500 yards, on a course W. by S. $\frac{1}{2}$ S., and so placed that the line of the breakwater produced should cut off 272 yards towards the sea. The design further required an entrance, between the sea end of the breakwater and the 24 feet curve of depth at the cape, of 500 yards; and between the two works, of 350 yards.

These works have not yet been completed to the extent of the design thus briefly described. The breakwater is in a course of construction for 862 yards, and the ice breaker for 467 yards. In other respects, the design of the harbor is necessarily incomplete. The entrances at the cape, and between the two works, are 780 yards and 455 yards, respectively, instead of 500 yards and 350 yards, as at first contemplated. It would thus appear that, on the one hand, the breakwater proper is 338 yards, and the ice breaker 33 yards, less; and, on the other, that the entrance towards the sea is 280 yards, and that between the works 105 yards, greater than the plan called for. In short, the lines of protection are less, and the entrances greater, by the quantities just given, than were originally designed.

During the progress of the work, as early as 1831, the customary surveys at the close of the operations of the season showed that deposits were forming about the works; and, among these, one just within and near the western end of the breakwater. These, however, were so small an extent, as not to attract much attention until 1834. In the autumn of that year they were found to have increased so much, as to cause serious anxiety respecting the ultimate usefulness of the harbor. When these facts were made known to the War Department, it ordered a board of survey to examine and report upon the subject. The report of the board is dated the 10th November, 1834, and closes, in substance, with the following opinions:

1st. That future operations should be confined to giving to the works the ultimate dimensions on their then present bases.

2d. That, in the mean time, numerous and careful surveys should be made to determine, with exactness, the increase of the shoals; and that a system of observations should be pursued as to the force and direction of the currents.

3d. That it would be premature, without a knowledge of the facts called for under the second head, to modify the original project.

The course recommended by the board was, without doubt, adopted for guidance in future operations.

The annual reports upon the works, from 1835 to 1839, inclusive, with the exception of that for 1838, distinctly state that neither work was extended during those years. Since 1839, as heretofore observed, all opera-

tions for continuing the work have, owing to a want of funds, been suspended. A comparison of the length of the works, as now existing, with those given in the annual report of 1833, confirms the opinion that the recommendation of the board on this point governed the operations. The length of the breakwater is almost identical; and any increase since that year in the length of the ice breaker, may be attributed to the necessity which, from time to time, existed for fortifying, by additional deposits, the east end of that work, which, from its exposed position, was liable to disruption.

The records of the office do not show that the measures which were recommended for ascertaining the enlargement of the shoals referred to were very satisfactorily pursued. It is true that surveys were made in 1834, 1835, 1836, 1840, and 1842; but, with the exception of that of 1842, these were almost wholly confined to a delineation of the bottom; and even on this point, owing to the want of knowledge of the plane of reference used in each case in the reduction of the soundings, no satisfactory comparison can be made, so as to arrive at any definite conclusion with regard to the increase of the shoals. Referring only to the shoals at the west end of the breakwater proper, (the only one from which any evil effects have arisen,) all that can, with certainty, be gathered from a comparison of the surveys, is, that, from the date of the first, up to the examinations of 1842, it has gradually increased. Some reasonable conclusions might be arrived at, if, with a statement of the order in which stone was deposited, information as to the rate of increase, or as to the time at which the shoal was at its maximum, had been given; but the surveys do not give these data. A hope, however, may be indulged, that, as the increase of the shoal has not been, of late, as great as it was in former years, (for the comparisons yield that information,) and as the bottom has had time, since the suspension of operations, to acquire its new *regimen*, this shoal, and, indeed, all the shoals resulting from the works, have nearly, if not fully, reached their utmost probable extent.

It must be confessed that, to a certain extent, the harbor, in its present state, answers the purpose of its original design, and that the results already justify the large expenditure incurred in its formation. Nevertheless, it must also be conceded that all that was anticipated from it has not been attained. Its objects were "to shelter vessels from the action of waves caused by the winds blowing from east to northwest, round by the north, and also, to protect them against injuries arising from floating ice descending from the northwest." The roll of the sea raised by the winds, particularly by the E.N.E. winds, which enters the gaps, and particularly that between the two works, exposes vessels lying in the harbor to considerable inconvenience, and occasionally to great hazard. The only position secure from the roll of the sea is immediately under the lee of the principal work; and it happens that this position, from the course of the ebb current, is the farthest removed from the effects of floating ice. Consequently, vessels in the harbor crowd to that point, and, as they occupy a very limited space, are in danger of being injured by each other at every shift of the wind or tide. But even from this refuge, imperfect as it is, vessels of the largest class are excluded, owing to the shallowness of the water. Nor does the harbor afford the security against floating ice which was contemplated by the original design. Not only are vessels exposed to the ordinary inconvenience and risk attendant upon running

ice, but there have been instances in which the whole fleet occupying the harbor has been at once carried out to sea by the floating masses.

To what extent these defects in the harbor are attributable to the nature of the original design, or to the unfinished state of the works, it seems to be useless now to consider, unless with a view to a suitable remedy. As heretofore intimated, the farther extension of the works was discreetly abandoned as soon as the shoal formations in the harbor were discovered. This course was especially prudent in relation to the breakwater proper—as its influence in causing the shoal in its immediate vicinity could not be doubted, even at that early period. It was also proper to postpone any modification of the design, until the works, as they were, should be raised to their ultimate height, and until further information in relation to the shoal formations should be obtained—which might, it was supposed, have a controlling influence on the measure. The works have now nearly attained this elevation; a single season will be sufficient for their completion. And although the information obtained may not be of a character that should give it value in elucidating the subject of the formation of shoals generally, it is sufficient to show, in contemplation of such a purpose, that the shoals in question are directly attributable to the existing works. The moment seems, therefore, to have arrived, when, if it is intended to consummate the design originally entertained for establishing a safe harbor at Cape Henlopen, suitable means should be adopted to carry into effect the measures indicated by the board of survey in the last resort—namely: a modification of the plan of the harbor. It is with a view to some proceeding of this kind that the undersigned, in the preceding remarks, has invited attention to the subject, and that he now begs leave to lay before the bureau, with such remarks and explanatory observations as the occasion calls for, the several propositions that have been made for so modifying the harbor as to remedy its present defects.

In order to remedy the defects of the harbor, which are caused by the roll of the sea entering between the works, three modes have been suggested:

- 1st. To cover the gap, by extending the icebreaker;
- 2d. To close the gap, by extending the breakwater proper; and
- 3d. To cover the gap by a detached work.

The general features of these plans were described in a report from this office, dated the 16th of September, 1839; and in that report a preference was avowed for the plan of a detached work. The views which were then entertained, have been substantially confirmed by personal observation during the late survey of the harbor. They will now again be referred to, and perhaps enlarged upon, in describing the plans, with the aid of details furnished during the same survey. And, in order that the entire subject may be viewed at a glance, estimates for the several plans will be presented, based upon the actual profile assumed by the present works—or, more properly, based upon the actual quantity of stone in the present works, and which experience has proved to be sufficient. Providing in each case for contingencies, there will be added the rate per cent. that has been heretofore paid on the cost of the stone. It may be proper, however, here to explain, that, as the quantity of stone is deduced from the actual quantity in works having four ends, a reduction is made in the case of the first plan, (which involves no new ends) of the stone required for four ends; in the instance of the second plan, as it joins two works, of six

ends; and in that of the third plan, (which calls for two ends,) of two ends. The data for these calculations and estimates are derived from the books of the office; and they are hereto annexed, as they may be useful for future reference.

The whole amount appropriated for the Delaware break-water	\$1,880,000
Cost of 835,020 tons of stone deposited, (average \$1 90.86 per ton)	\$1,593,271 38
Contingent expenses 17.963 per cent. (average 34.284 cents per ton)	286,728 62
	<u>1,880,000</u>

Prices paid for stone used in the construction of the Delaware break-water.

Years.	Pieces of 1½ to 2 tons.	Pieces of 2 tons and upwards.	Remarks.
1829	\$2 20 per perch	\$2 20 per perch	} \$2 20 per perch of 2,656 lbs. was paid during these years for stone, without discriminating between the large and the small sizes.
1830	2 20 "	2 20 "	
1831	2 20 "	2 20 "	
1832	1 80 per ton	2 50 per ton	Pennsylvania quarries. Delaware quarries.
1833	1 80 "	2 50 "	
1834	1 74 "	2 44 "	
1835	1 74 "	2 44 "	
1836	1 74 "	2 44 "	
1837	1 75 "	2 45 "	
1837	1 80 "	2 50 "	
1838	2 00 "	2 75 "	
1839	2 00 "	3 00 "	

Cost of stone, by commissioners' estimate, \$2 20 per perch of 25 cubic feet. Contingencies 2½ per cent.

Tons.

Quantity of stone, by original design, for two works having an aggregate length of 1,700 yards founded in 29.4 feet water, at low water of spring tides, and elevated 12 feet above the same plane	1,890,628
Quantity of stone to raise the same to 15 feet above low water of spring tides, (a change contingently provided for by the original design)	Tons. 30,600
Quantity of stone for four ends, not provided for by the original design	95,920
	<u>126,520</u>
Whole quantity of stone for two works, as above	<u>2,017,148</u>

	Tons.
Quantity of stone (deduced from the original design) for two works having an aggregate length of 1,320.33 yards founded in 29.4 feet water, at low water of spring tides, and elevated 15 feet above the same plane - - - - -	1,493,153
Quantity of stone for four ends, not provided for by the original design - - - - -	95,920
Whole quantity of stone for two works, as above - - - - -	<u>1,589,073</u>
Quantity of stone now forming the two works, having an aggregate length of 1,320.33 yards, and founded in 29.4 feet water, at low water of spring tides - - - - -	835,020
Quantity of stone to finish the same to 15 feet above low water of spring tides - - - - -	24,953
Whole quantity of stone for two works, as above - - - - -	<u>859,973</u>

Difference in the quantity of stone actually deposited and required for two works, as above, and by the original design, 729,100 tons.

I. To cover the gap between the works, by extending the icebreaker.

This proposition was made in the annual report of 1836. It is, in effect, to prolong the icebreaker towards the sea, on a curve line passed over by the ebb current, until it meets a northeast line drawn from the west end of the breakwater proper, and leaving between it and the latter work a passage of 280 yards, measured across the tide. The length of the work, as defined above, would be 570 yards.

The advantages anticipated from this change would be, that all direct waves produced by winds from northwest to northeast, round by the north, would be intercepted, and the object of shelter would be gained, without increasing the area of the slackwater. It is, moreover, thought that, although the storm-waves raised by more easterly winds would still roll into the harbor, their force would be so much reduced that no injury would be suffered by the shipping.

The objections to this plan are, that the work is likely to increase the present shoals within the harbor, if not to produce new ones; that a portion of the work is opposed to winds that are harmless in their effects upon the harbor, while it is at the same time exposed to the effects of the most violent winds; and that the gap between the works would be rendered nearly useless as an entrance to the harbor.

No serious objection can be urged against the position of the proposed work with reference to the ebb current. Even if the work should not be on the thread of the stream, any accumulation that might be formed, would, from the accelerated velocity of the current passing through the gap, in all probability be deposited on the outside of the work. It is not equally probable, however, that no greater evils would result from the influence of the flood current. The reduced volume of water entering the gap on the flood current, and the new direction given to that current by the work, would probably cause an extension of the shoal within the breakwater towards the west, now limited by the present volume and direction, if it would not create a new shoal within the prolongation itself.

In considering the second objection, it is necessary to premise that all winds from the N.E. to E.S.E., round by the north, are, at the harbor

of the breakwater, land winds. Those between the same points round by the east, are winds that blow off the sea. The first winds off the land, proceeding towards the north, against which protection is required, are the northwest winds. Against these the icebreaker already affords this protection. These winds are succeeded by others from a considerable segment about the north. They are of rare occurrence; and when they do blow, it is without violence. It is believed that vessels lying in the harbor have experienced no inconvenience from winds in this direction, except in one instance. It is against these that a portion of the proposed work is opposed, and which might, it is presumed, be omitted, without materially affecting the safety of the anchorage.

Again: the seaward end of the prolongation is limited by a line drawn from the west end of the breakwater proper, towards the northeast one of the boundaries, as before stated, of the seaward segment. It is from this segment, and especially from the E.N.E. point, that the most destructive waves proceed; and here protection is most required. To these waves the harbor would be exposed for a breadth of about 115 yards, and, so far, fails to yield entire security to the shipping. In short, that which is of little use, and which might be spared from one end, might be profitably applied to the other.

The greatest objection to the proposition, however, is, the reduced width contemplated for the entrance between the works; and, above all, the inconvenient character given to that entrance. It is the one principally used by vessels entering the breakwater for a harbor. The width proposed for it by the original design was 350 yards; its present width, as already stated, is 455 yards—which is considered little enough for safe ingress and egress for vessels of a large size. The plan now proposed reduces the width to 280 yards only—70 yards less than the first, and 175 yards less than the second. But even if the width of the entrance were equal to the larger one, the character that is given to it should forbid the adoption of the plan, unless under the most pressing necessity. The passage to and from the harbor, that is now made between the ends of the two works, would, in that event, be made between the end of one work and the line of the other; through which, as a strait, vessels would work at much inconvenience and no little hazard.

Again: vessels descending the bay with a free wind, and intending to enter the harbor, (but not between the icebreaker and the shore—a course usually avoided,) would have to haul their wind, in order to double the point of the projected work, and would, probably, have to make one or more tacks to enable them to reach the anchorage; whereas the entrance at present admits an easy ingress, with only a slight change of course.

Of the plans under consideration, the one thus particularly noticed is more expensive than the second, and less expensive than the third one.

Estimate to cover the gap between the works, by extending the icebreaker.

Length of work, 570 yards; depth of water, 28.7 feet at low water of spring tides.

	Tons.
Quantity of stone, deduced from the works already constructed	358,338
Deduct for four ends, deduced as above	55,091
Whole quantity of stone	<u>303,247</u>

As follows :

84,690 tons, of pieces of two tons and upwards, at \$3	-	\$254,070 00
218,557 tons, of pieces of $\frac{1}{4}$ to 2 tons, at \$2	-	437,114 00
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Cost of stone	-	691,184 00
Contingent expenses, 17.963 per cent.	-	124,157 38
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Total cost of the proposed work	-	815,341 38
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Amount expended at the harbor of the Delaware break-water	-	\$1,880,000 00
Cost of the proposed work, as above	-	815,341 38
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Total cost of the harbor, as modified by the above plan	-	2,695,341 38
Total cost of the harbor, by the original estimate	-	2,216,950 46
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Excess over the original estimate	-	478,390 92
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II. To close the gap between the works, by extending the breakwater proper.

This proposition was for the first time formerly made in a report, dated the 5th of August, 1839, by the officer then in the immediate charge of the work; and was renewed in the annual reports of the same officer, dated the 13th November of the same year, and the 5th of November, 1840. For the particular views under which this modification of the plan of the harbor was recommended, the bureau is respectfully referred to the reports just mentioned. To those views, and to the modification itself, objections were urged in a special report, heretofore alluded to, dated the 16th September, 1839; and in the letters dated the 14th of November of the same year, and the 6th of November, 1840, transmitting the annual reports above mentioned. As these reports are on file in the bureau, it is not deemed necessary here to state, in detail, these objections. They were, in substance, as follows: That the deflection of the flood current by the icebreaker had little to do with the formation of the shoal within the breakwater; that the breakwater, lying at an angle with the flood current, causes an eddy on its leeward side within the harbor, from which a deposit is made; and that the shoal so formed is limited on the south by the flood current tangent to the east end of the breakwater, and on the west by the influx of the same current through the gap between that work and the icebreaker. These facts and views being considered indisputable, the report concludes with the opinion, that, as the plan increases the length of obstruction to the flood current, by the distance between the west end of the breakwater and west end of the icebreaker, at the same time that it removes the causes that limit the length of the shoal in question towards the west, that shoal would gradually extend until it reached the west end of the icebreaker. Any further extension of the breakwater was, therefore, deemed inadmissible; and, as a consequence, the plan to close the gap by that mode was not approved of. The cost of this plan, as it calls for a work of only 455 yards in length, is much less than that of either of the other two.

Estimate to close the gap between the works, by extending the breakwater proper.

Length of work, 455 yards; depth of water, 27.3 feet at low water of spring tides.

	Tons.
Quantity of stone, deducted from the works already constructed - - -	271,033
Deduct for six ends, deducted as above - - -	67,248
Whole quantity of stone - - -	<u>203,785</u>

As follows:

60,064 tons, of pieces of 2 tons and upwards, at \$3 -	\$180,192 00
143,721 tons, of pieces of $\frac{1}{4}$ to 2 tons, at \$2 -	287,442 00
Cost of stone - - -	467,634 00
Contingent expenses, 17.963 per cent. - - -	84,001 10
Total cost of the proposed work - - -	<u>551,635 10</u>
Amount expended at the harbor of the Delaware breakwater - - -	\$1,880,000 00
Cost of the proposed work, as above - - -	551,635 10
Total cost of the harbor, as modified by the above plan -	2,431,635 10
Total cost of the harbor by the original plan and estimate -	2,216,950 46
Excess over the original estimate - - -	<u>214,684 64</u>

III. To cover the gap by a detached work.

The conditions of this plan were also stated in the report of the 16th of September, 1839. The recent survey has supplied the data governing the details of the plan, which may thus be described: The work lies N. 77° 30 W., the course of the flood current, and occupies the space included between the parallels, drawn in one case from the west end of the breakwater, and in the other from the east end of the icebreaker, in the direction of the E.N.E. winds. These conditions call for a work 570 yards in length. The water-way at the nearest point between the detached work and the existing works is assumed at 455 yards, the present width of the gap.

It is conceived that the advantages of this plan are, that the work covers the entire opening between the existing works, in the direction of the winds causing the largest waves entering the harbor; that it detracts nothing from the facilities afforded by the present entrance; that, by coinciding with the direction of the current, it will not cause deposits in the form of shoals; that, as it is detached, it may be constructed from a central point in both directions, until the necessary protection is afforded, which, it is confidently believed, may be effected far short of the length assigned to it.

The defect of the plan is, that the direct waves from the northeast would still enter the western part of the harbor for a width of 175 yards

between the parallels drawn from the west end of the work and the east end of the icebreaker. At present, these waves enter the harbor between the same parallels, for a width of 455 yards. This defect, however, as the work admits of indefinite extension, may be remedied at the sacrifice of additional cost. No apprehension is felt as to the formation of any deposite resulting from the ebb current, (the two currents forming an angle with each other of ten degrees,) as it would occupy the immediate margin of the work, and, instead of being an injury, might help to consolidate it.

The plan is open also to the objection, that, being detached, it gives to the works of the harbor two additional weak points; whereas the first plan calls for no additional weak points, and the second actually reduces these from three to two. It also involves the largest expenditure.

Estimate to cover the gap by a detached work.

Length of work, 570 yards; depth of water, 30.5 feet at low water of spring tides.

	Tons.
Quantity of stone, as deduced from the works already constructed	388,560
Deduct for two ends, deduced as above	28,201
Whole quantity of stone	<u>360,359</u>

As follows:

92,812 tons, of pieces of 2 tons and upwards, at \$3	\$278,436 00
267,547 tons, of pieces of $\frac{1}{4}$ to 2 tons, at \$2	535,094 00

Cost of stone	813,530 00
Contingent expenses, 17.963 per cent.	146,134 39

Total cost of the proposed work	<u>959,664 39</u>
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Amount expended at the harbor of the Delaware break-water	\$1,880,000 00
Cost of the proposed work, as above	959,664 39

Total cost of the harbor, as modified by the above plan	2,839,664 39
Total cost of the harbor by the original plan and estimate	<u>2,216,950 46</u>

Excess over the original estimate	<u>622,713 93</u>
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In order that a comparison may be made between the cost of the several plans now submitted, and the cost for completing the works to the lengths originally proposed, the following estimate, calculated from the same data, is subjoined:

Aggregate length of works, 379.66 yards; depth of water, 29.4 feet at low water of spring tides.

	Tons.
Quantity of stone, as deduced from the works already constructed	247,289
Deduct for four ends, deduced as above	55,067
Whole quantity of stone	<u>192,222</u>

As follows :

51,815 tons, of pieces of 2 tons and upwards, at \$3	-	\$155,445 00
140,407 tons, of pieces of $\frac{1}{4}$ to 2 tons, at \$2	-	280,814 00
		<hr/>
Cost of stone	-	436,259 00
Contingent expenses, 17.963 per cent.	-	78,365 20
		<hr/>
Total cost to extend the works	-	514,624 20
		<hr/>
Amount expended at the harbor of the Delaware break-		
water	-	\$1,880,000 00
Total cost to extend the works, as above	-	514,624 20
		<hr/>
Total cost of the harbor, by completing the works to the		
lengths originally proposed	-	2,394,624 20
Total cost of the harbor by the original plan and estimate	-	2,216,950 46
		<hr/>
Excess over the original estimate	-	177,673 74
		<hr/>

It is believed that no plan has been devised to correct the evils in the harbor caused by running ice. One is incidentally alluded to in the annual report of 1836, and the imperfection of it is clearly demonstrated. Any structure on the course of the current would not afford protection against running ice; and one of stone across the current would, by impeding it, create shoals that would injure, if not destroy, the harbor. The great desideratum is, to be able to obstruct the ice, without obstructing the free course of the current. In order to accomplish this result, the application of the iron screw pile has been suggested in former reports. These piles, it is conceived, may be so combined as to constitute a complete barrier against the passage of the floating ice, at the same time that the current is allowed to flow in its accustomed course, and with the same velocity. It is, in all respects, worthy of consideration, whether a fair experiment, conducted with liberal means, ought not to be made, in order to ascertain clearly whether the iron screw-pile may not be successfully applied to this purpose. The result, if favorable, would constitute an epoch in the construction of ice-harbors, and would lead to kindred applications of much importance. It is with a view to such an experiment, that an item for iron screw-piles is included in the estimate of the operations for the next season. In using such piles in the formation of an ice-harbor, they may either form a continuous work, composed of rows in quincunx order, or constitute piers at certain intervals, as may be deemed advisable, after proper investigations. Under any form of combination, the piles should be braced horizontally, by bars of iron, at low water and at the top, in order that the shock caused by the ice may be sustained, not by one pile, but by numerous contiguous piles. In adopting the work just described as a remedy for the defect in the harbor of the Delaware breakwater, arising from running ice, it should commence at the west end of the icebreaker, and extend towards the shore, on the shortest line, until the required protection is gained.

In submitting a modification of the design of the Delaware breakwater, and in making these several suggestions, it is not with a de-

sire that they should be now adopted. The harbor is of so much importance, that no change should be made in it at the instance of an individual. It is again, therefore, earnestly recommended "that, whenever it shall be determined to extend the works beyond their present limits, a board of officers of experience be formed, to report what, if any, modifications are, in their opinion, necessary to carry out the design originally had in the formation of the harbor."

I have the honor to be, very respectfully, your obedient servant,

HARTMAN BACHE,
Corps Top. Eng., Brevet Major.

Colonel J. J. ABERT,
Bureau of Top. Engineers.

